Directional Properties of Surface Waves Observed with HF Radar

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LONG-TERM GOALS

My long term goal is to demonstrate that wave measurements obtained using HF radars are of sufficient accuracy and availability for them to contribute to the investigation of changes to the directional spectrum of waves subject to meteorological, bathymetric and current variability in coastal environments for both scientific and operational applications.

OBJECTIVES

My objectives for this program of research are:

a) to measure the directional properties of surface waves in the coastal ocean using the University of Miami OSCR HF radar;

b) to validate the measurements using other available data sources;

c) to measure the evolution of the directional spectrum as the waves shoal;

d) to determine the response of the directional spectrum to surface current shears and variable bottom bathymetry.

APPROACH

In the fall of 1999 the Shoaling Waves Experiment (SHOWEX) took place in the coastal waters of Duck, NC, USA. The University of Miami group deployed their OSCR HF radar at the FRF site, Duck, and at Corolla to provide measurements of the directional wave spectrum, surface currents and wind direction. Due to limitations in the OSCR hardware, continuous data collection throughout the experiment was not expected but the aim was to collect as much data as possible simultaneously at the two sites in order to maximise the chances of capturing different wave events. Directional spectrum measurements are made using a method I have developed over the last few years (see Wyatt 1990, Holden and Wyatt 1992, Wyatt et al. 1999 and Wyatt 2000). The wave spectrum measurements will be subject to detailed intercomparisons with in-situ instruments to complement existing comparisons from experiments in Europe. In the light of this, possible improvements and/or enhancements to the measurement methods will be explored. Once the data have been validated I will collaborate with other participants in the experiment in reaching the wave science goals.

WORK COMPLETED

I visited the radar sites at the end of October 1999, accompanied by a radar hardware expert, Simon Kingsley of the University of Sheffield, to check on the data quality and establish whether signal to noise was going to be sufficient for the wave measurement application. Some modifications were made in an attempt to improve the performance of the antennas. However the most significant change that we made was to change the pulse length of the radar transmission to increase the range performance so that wave measurement would be achievable without the need to move one of the radar sites.

Data has been collected during the experiment from the 3rd of November to the 15th of December 1999 and its initial processing to provide Doppler spectra has been accomplished. There are some gaps in the coverage for a number of reasons associated with the performance of the radar and its data handling capabilities. We have processed data for the dates 3-14, 17 Nov, 1-2, 6-15 Dec. In total we have about 400 hourly measurements suitable for further processing. The University of Miami are investigating the possibility that more data can be recovered from tapes that suffered from recording errors. The central part of the data processing consists of inverting the radar Doppler spectra to obtain directional wave spectra. The inversion software has been subject to some modifications in the last few months, particularly concerning the assessment of data quality required for inversion, and we are testing these modifications on the SHOWEX data set to choose the optimal one before carrying out a full validation. Meanwhile preliminary results have been obtained.

RESULTS

It is too soon to present detailed results. I present preliminary results to demonstrate that the data collected provide reasonable spatial coverage and show qualitative agreement with the buoy data we have looked at so far.

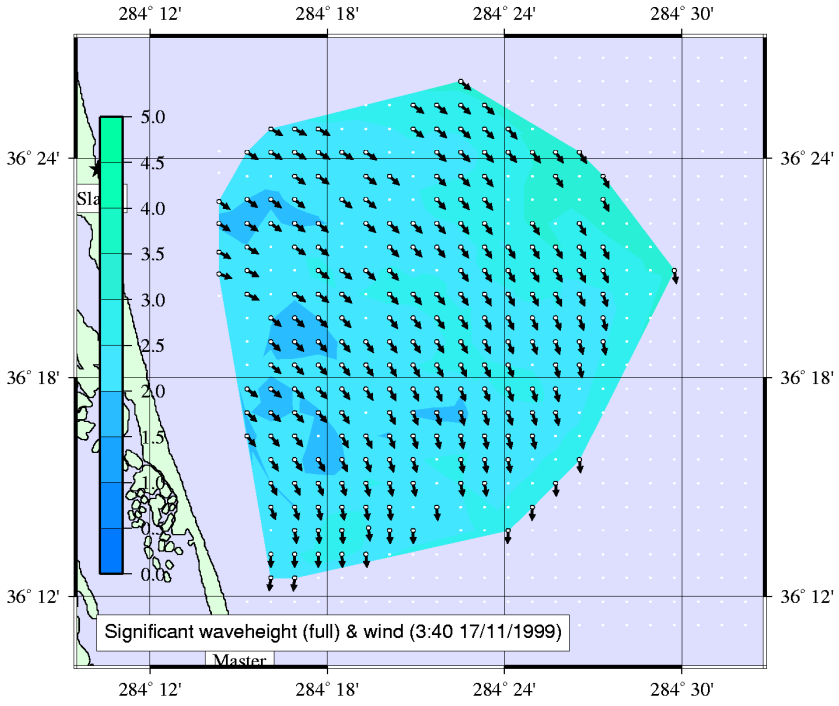

Figure 1. Typical map of radar-derived significant waveheights and wind directions

Figure 1 shows a map of the region with color-coded significant waveheights and radar-derived wind directions (Wyatt et al, 1997) giving some idea of the coverage that is achievable with OSCR. Figure 2 shows a time series comparison of OSCR at a location in the centre of the region with the X2 buoy (not-colocated but shown to give both an impressions of the accuracy of the radar data and to show the temporal coverage). Note that we show parameters that are available, at the time of writing, on the buoy web site. The first two, peak direction and period, are of course subject to significant statistical variability. In addition the radar measurements of these parameters are often contaminated with antenna sidelobe influences and hence are rather noisy. In Figure 3 a comparison of sample directional spectra, at 04:00 on 4th of November, as well as of the corresponding frequency spectrum, S(f), mean direction, $\theta(f)$, and directional spread, $\sigma(f)$, obtained by the radar and the BRAVO ASIS buoy are shown. This is the first comparison between our radar measurements and a directional spectrum obtained using maximum likelihood estimation from an array of wave staffs. A detailed statistical analysis will be carried out between the radar and all instruments where co-locations are available when we receive the rest of the buoy data.

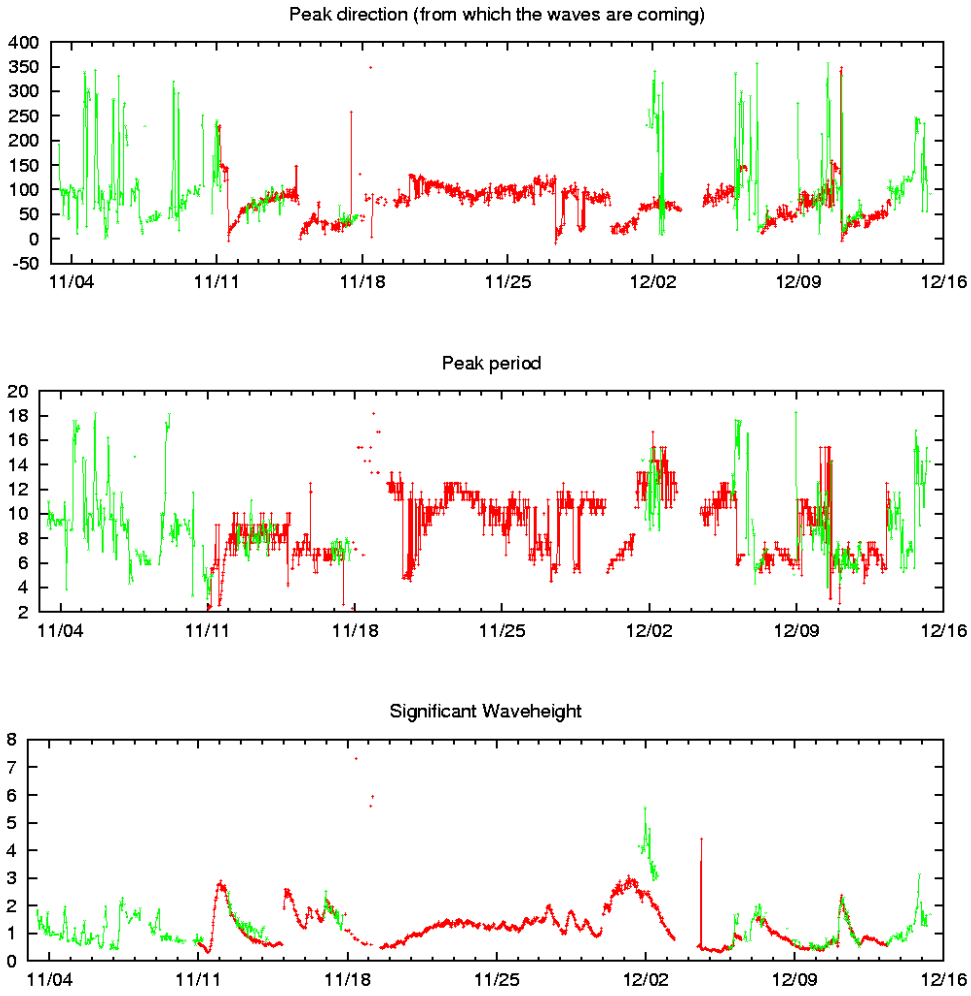

Figure 2: Comparison of Buoy X2 (red) and OSCR (green) parameters

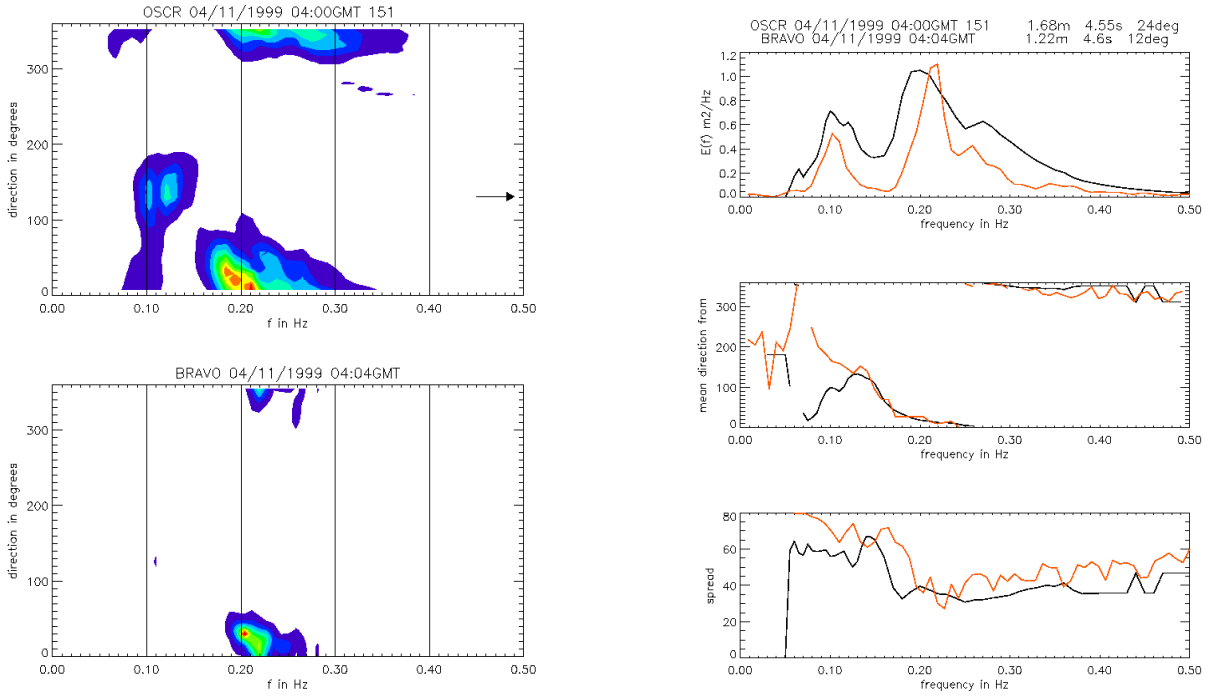

Figure 3: Sample directional spectra comparison on the left colour coded with 10 levels at intervals of 10% of the maximum in each, OSCR on the top, BRAVO below. Parametric spectra comparison on the right, OSCR black, BRAVO red.

IMPACT/APPLICATIONS

Our participation in the SHOWEX experiment provides an opportunity to bring the wave measurement potential of HF radar, and in particular the spatial picture of wave development that it provides, to the attention of a wider community. Whilst there are still some factors that limit the availability and accuracy of the measurements in some circumstances, the spectral, spatial and temporal resolution of the measurements provides a unique wave measurement capability.

Comparisons between HF radar measured directional spectra and maximum entropy estimated directional waverider spectra using other data sets have shown some interesting similarities and differences. In SHOWEX we have the opportunity to include for the first time maximum likelihood estimated directional spectra (from the Miami ASIS buoys) which may help to resolve some of the issues that have been raised in the earlier work.

TRANSITIONS

The measurements will be made available to other participants in SHOWEX as soon as we have decided on the optimum data quality management procedure and processed the data accordingly.

We are providing the University of Miami with an inversion software package to test the transportability of the algorithms. This is subject to an agreement between the two Universities.

RELATED PROJECTS

The wave measurement software is also being validated in an EU-funded project, EuroROSE, using the German WERA radar deployed at sites in Norway and Spain. The Norwegian data has been driving the software modification effort already referred to and has also provided a large amount of high sea-state data to complement the lower sea-state, probably more swell-dominated, data of SHOWEX.

Sofia Caires is just completing a PhD at the University of Sheffield under my supervision developing statistical techniques for intercomparison of wave measurements and models which allows for the estimation of variances in the wave parameter estimates. This work will provide us with some of the tools needed for the intercomparison work we are planning over the next few months.

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PUBLICATIONS

No publications to date.